APPENDIX G: Methodology and Adjustments to Approaches Used to Estimate Nitrous Oxide Emissions from Agricultural Soils

This appendix presents the methodology and country-specific approaches that EPA used to estimate N_2O emissions from agricultural soils. EPA estimated N_2O for five components of N_2O emissions from agricultural soils:

- Direct Emissions from Commercial Synthetic Fertilizer Application;
- Direct Emissions from Cultivation of Nitrogen-Fixing Crops;
- Direct Emissions from the Incorporation of Crop Residues;
- Direct Emissions from Daily Spread Operations and Direct Deposition; and
- Indirect Emissions from Agricultural Soils.

Direct Emissions from Commercial Synthetic Fertilizer Application[1]

Historical activity data: FAO publishes historical commercial synthetic fertilizer consumption data for most developed countries (FAO, 1998a). The following assumptions were made for countries without data:

- Luxembourg: FAO reported fertilizer consumption statistics for Belgium and Luxembourg together. The N_2O emissions from agricultural soils, as reported in each country's National Communications, were used as a proxy to divide consumption among the two countries. This resulted in 98 percent of the fertilizer consumption attributed to Belgium and 2 percent to Luxembourg.
- Croatia, Estonia, Latvia, Lithuania, Russia, Ukraine: The data for these countries were aggregated in 1990, as they were part of the Former Soviet Union. Disaggregated 1992 data replaced the data used for 1990.
- Czech Republic and Slovakia: In 1990, the Czech Republic and Slovakia were part of Czechoslovakia, and the fertilizer consumption data was reported jointly. The disaggregated 1995 data served as a model to determine 1990 values for the Czech Republic.
- Liechtenstein: No data are available.

Projected activity data: Using the 1995 and 2000 regional fertilizer consumption data from FAO, EPA determined the 1995-2000 growth rate for each region (FAO, 1998d). These regional growth rates were used to linearly extrapolate fertilizer consumption to 2010.

Historical and Projected Emissions: As recommended in the *Revised 1996 IPCC Guidelines*, the assumption for this analysis was that 1.25 percent of all nitrogen from fertilizer consumption, excluding the 10 percent of nitrogen in fertilizer that volatilizes as NO_x and NH_3, is directly emitted as N_2O (IPCC, 1997). Therefore, emissions were calculated as follows:

[1] Organic fertilizer application was not included due to a lack of available data.

$$N_2O = [F_{country} - (F_{country} * 10\%)] * 1.25\%$$

Where,

$F_{country}$ is the nitrogen from fertilizer consumption for the specified year and country.

Direct Emissions from Cultivation of Nitrogen-Fixing Crops[2]

Historical activity data: The FAOSTAT database provided historical crop production statistics for soybeans and pulses (FAO, 1998b).

Soybeans. In 1995, eighteen developed countries produced soybeans. For 1990, FAO reported data for the Czech Republic and Slovakia together. Similarly, FAO only provided data for the former Soviet Republics as a whole. In all cases, the disaggregated 1993 data served as a model to disaggregate the combined 1990 data.

Total Pulses. In 1995, 32 developed countries produced pulses.

- Croatia, Czech Republic, Slovakia, Estonia, Latvia, Lithuania, Russia, and Ukraine: Data for 1992 was used to determine production shares in 1990.
- Luxembourg: The Belgian pulse production data included Luxembourg. To determine percentage allocations, EPA used N_2O emissions from all agricultural sources, as reported in their individual National Communications, as a proxy (98 percent Belgium; 2 percent Luxembourg).

Projected activity data:

Soybeans. FAPRI reported projected soybean production data for 2000 and 2005 for regions and a limited number of countries, and at the global level (FAPRI, 1997). For countries without production projections, EPA used the regional growth rates. The growth rates were also used from 2005 to 2010.

Total Pulses. In the absence of pulse production projections, EPA assumed that pulse production grew at the same rate as soybean production. For countries growing pulses only, EPA applied the regional soybean production growth rates (Exhibit F-9).

Historical and projected emissions: The crop production statistics account for only the mass of the crop product rather than the entire plant. The data were expanded to total crop mass, in units of dry matter, by applying residue to crop mass ratios and dry matter fractions for residue (Strehler and Stutzle, 1987). To convert to units of nitrogen, EPA applied the IPCC recommendation that 3 percent of the total crop dry mass for all crops was nitrogen (IPCC, 1997).

Direct Emissions from the Incorporation of Crop Residues

Historical activity data: Residues from corn, wheat, beans and pulses are typically incorporated into soils. Bean and pulse production were estimated in the previous section. FAO provided historical production data for corn and wheat for most countries (FAO, 1998b). EPA made adjustments for several countries' corn and wheat production:

- Luxembourg: The Belgian production data included Luxembourg. To determine percentage allocations, EPA used N_2O emissions from all agricultural sources, as reported in their individual National Communications, as a proxy (98 percent Belgium; 2 percent Luxembourg).
- Czech Republic and Slovakia: FAO provided the individual country's production statistics for 1995, which were used to determine relative shares that EPA applied to the 1990 data reported for Czechoslovakia.

[2] Alfalfa was not included in the analysis due to lack of data.

- Latvia, Lithuania, Russian Federation, Slovenia, Ukraine: The data reported for 1995 filled in the gap for 1990.
- Croatia, Iceland, Liechtenstein: No data were available.

Historical emissions: As recommended in the *Revised 1996 IPCC Guidelines,* EPA assumed that 55 percent of all crop residues are returned to the soils (IPCC, 1997). Crop residue biomass, in dry matter mass units, was calculated by applying residue to crop mass ratios and dry matter fractions for residue (Strehler and Stutzle, 1987). For beans and pulses, an estimated 3 percent of the total crop residue was nitrogen (IPCC, 1997). For wheat and corn, Barnard and Kristoferson (1985) report nitrogen contents. Using the IPCC default, 1.25 percent of all nitrogen from incorporated residues is directly emitted as N_2O.

Projected Emissions: Nitrous oxide emissions from incorporation of crop residue grew in proportion to production. Using the growth rates from FAPRI and assuming that the growth-rate from 2000-2005 remains constant through 2010, EPA projected emissions to 2010.

Direct Emissions from Daily Spread Operations and Direct Deposition

Direct nitrous oxide emissions result from livestock wastes that do not enter the commercial fertilizer market but are instead "applied" to soils, either through daily spread operations or direct deposition on pastures and paddocks by grazing livestock.

Historical activity data: FAO reported historical animal population data for most countries (FAO, 1998c), with the following exceptions:

- Luxembourg: The Belgian population data included Luxembourg. To determine percentage allocations, EPA used N_2O emissions from all agricultural sources, as reported in their individual National Communications, as a proxy (98 percent Belgium; 2 percent Luxembourg).
- Croatia, Estonia, Latvia, Lithuania, Russia, and Ukraine: Data for 1990 are reported for the Former Soviet Union. EPA allocated the 1990 livestock populations in the Former Soviet Union among Estonia, Lithuania, Russia, and Ukraine based upon each country's relative share in 1995. The 1995 data filled the gap for 1990 for Croatia.
- Czech Republic and Slovakia: In 1990, production statistics were reported for Czechoslovakia. Each country's 1995 production statistics were used to determine relative shares.
- Liechtenstein: No data were available.

Historical emissions: EPA divided total livestock nitrogen excretion, calculated for each animal type, among animal waste management systems using IPCC default assumptions. EPA applied the IPCC default that 20 percent of total annual excreted livestock nitrogen was volatilized (IPCC, 1997). Finally, the remainder of the excreted livestock nitrogen was multiplied by IPCC default emission factors specific to the animal waste management system.

Projected Emissions: Animal population forecasts were not available. EPA assumed that emissions would grow at the same rate as methane emissions from manure, as reported in the National Communication.

Indirect Emissions from Agricultural Soils

This component accounts for N_2O that is emitted indirectly from nitrogen applied as fertilizer and excreted by livestock. Nitrous oxide enters the atmosphere indirectly through one of two pathways: 1) leaching and runoff of nitrogen from fertilizer applied to agricultural fields and from livestock excretion; and 2) atmospheric deposition of NO_x and NH_3 (originating from fertilizer use and livestock excretion of nitrogen). Emissions from each of these pathways are described below.

- **Emissions from fertilizer consumption**: Nitrogen consumption data and forecasts, determined for the fertilizer application section, were used to calculate indirect N_2O emissions. The IPCC recommends that 10 percent of the applied synthetic fertilizer nitrogen volatilizes to NH_3 and NO_x, and 1 percent of the total volatilized nitrogen is emitted as N_2O (IPCC, 1997). To estimate emissions from leaching and run-off, EPA uses the IPCC recommendation that 30 percent of the total nitrogen applied is lost to leaching and surface runoff, and 2.5 percent of this lost nitrogen is emitted as N_2O (IPCC, 1997).
- **Emissions from livestock excretion**: Historical estimates of total livestock excretion, as calculated under the nitrous oxide emissions from livestock manure section, were used to calculate the historical emissions. According to the IPCC, 20 percent of nitrogen in livestock excretion volatilizes to NH_3 and NO_x, and one percent of the total volatilized nitrogen is emitted as N_2O (IPCC, 1997). To estimate emissions from leaching and run-off, EPA used the IPCC recommendation that 30 percent of the total nitrogen applied is lost to leaching and surface runoff, and 2.5 percent of this lost nitrogen is emitted as N_2O (IPCC, 1997). Livestock excretion projections for 2000, 2005, and 2010 were not available. Therefore, the indirect emissions from animal waste were expected to grow at the same rate as direct emissions from animal waste, as determined in the methane emissions from livestock manure section.